

Appendix B

Example of an Engineering Safety Note

An engineering safety note is a management-approved (by division leader or higher) document that describes the anticipated hazards associated with a piece of equipment or a process. It describes the Responsible Individual's approach, analysis, and rationale used to assure the design safety of the equipment, system or process. An ESN does not have to be prepared by a member of the Engineering Directorate as long as the individual is technically qualified to prepare the ESN.

The new designations for ESNs are as follows:

- Mechanical Engineering Safety Note, MESN 99-001-OA
- Electronic Engineering Safety Note, EESN 99-001-OA
- Livermore Laboratory Safety Note, LLSN 99-001-OA

Assignment of a safety note number is controlled by the Engineering Records Center, Building 131, Room 1518.

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Mechanical Engineering Safety Note

500 PSIG Test Vessel

by

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October 1999

Approved by:

Responsible Individual

Pressure Consultant

Division Reviewer

Division Leader

Distribution

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500 PSIG Test Vessel

A. Description

This Safety Note covers test vessel used to contain inert, liquid, or gas at pressures up to 500 psig. The vessel comprises a cylindrical section made of machined stainless steel pipe (8-inch nominal pipe size, schedule XXS) with a threaded/welded bottom and flanged/o-ring sealed lid. Three feed-throughs enter the lid via threaded pipe connections (2 ports are 1/2 inch pipe size; 1 port is 1/8 inch pipe size). LLNL Drawing Number AAA88-111390 (attached) describes this vessel.

B. Hazard

This vessel represents a potential hazard to personnel and equipment when pressurized to 500psi with liquid or gas. The latter case involves the greater stored energy and will therefore be calculated. The energy contained in the gas, assuming a reversible adiabatic (isentropic) expansion, is given by:

$$E = \frac{P_1 V_1}{K - 1} \left(1 - \frac{P_2}{P_1} \right)^{\frac{K-1}{K}} \quad (\text{Page C-11, Ref. [11]})$$

Where

- P_1 = MAWP
- P_2 = Atmospheric pressure
- V_1 = Volume of the vessel
- K = C_p/C_v = Ratio of specific heats
- E = Stored energy

For this design:

- P_1 = 500 psia
- P_2 = 14.7 psia
- V_1 = 11,305 cc
- K = 1.4 for air or nitrogen (worst case)

Adjusting this equation for the proper units and substituting values gives:

$$E(\text{gmTNT}) = 1.492 \times 10^{-6} \frac{P_1(\text{psi})V_1(\text{cc})}{K - 1} \left(1 - \frac{P_2}{P_1} \right)^{\frac{K-1}{K}}$$

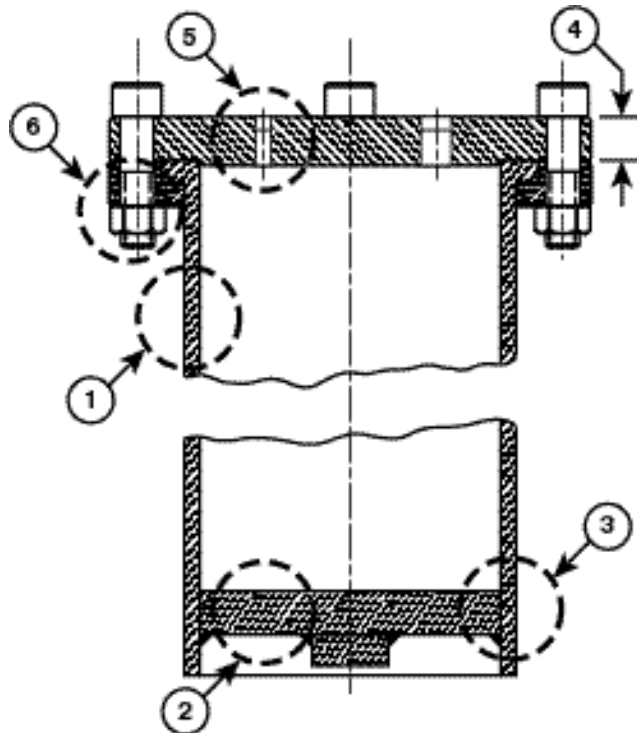
$$E(\text{gmTNT}) = \frac{1.492 \times 10^{-6} \times 500 \times 11,305}{1.4 - 1} \left(1 - \frac{14.7}{500} \right)^{\frac{1.4-1}{1.4}}$$

$$E(\text{gmTNT}) = 13.4 (\text{gmTNT})$$

C. Calculations

For this vessel, the following design features will be analyzed:

1. Cylindrical hoop stress
2. Bottom thickness
3. Bottom thread shear
4. Lid thickness
5. Lid feed-throughs
6. Bolt/nut thread stress



Design details for this vessel are as follows:

- 32°F to 130°F temperature operation
- Gasket seal = o-ring

- Vessel materials
 - Cylinder: 304 stainless steel per SA-479
 - Allowable stress: $S_{a-v} = 18.800$ psig (Ref. 2)
 - Yield stress: $S_y = 30,000$ psig
 - Allowable stress: $S_{a-v} = 18.800$ psig (Ref. 3)

- Bolts

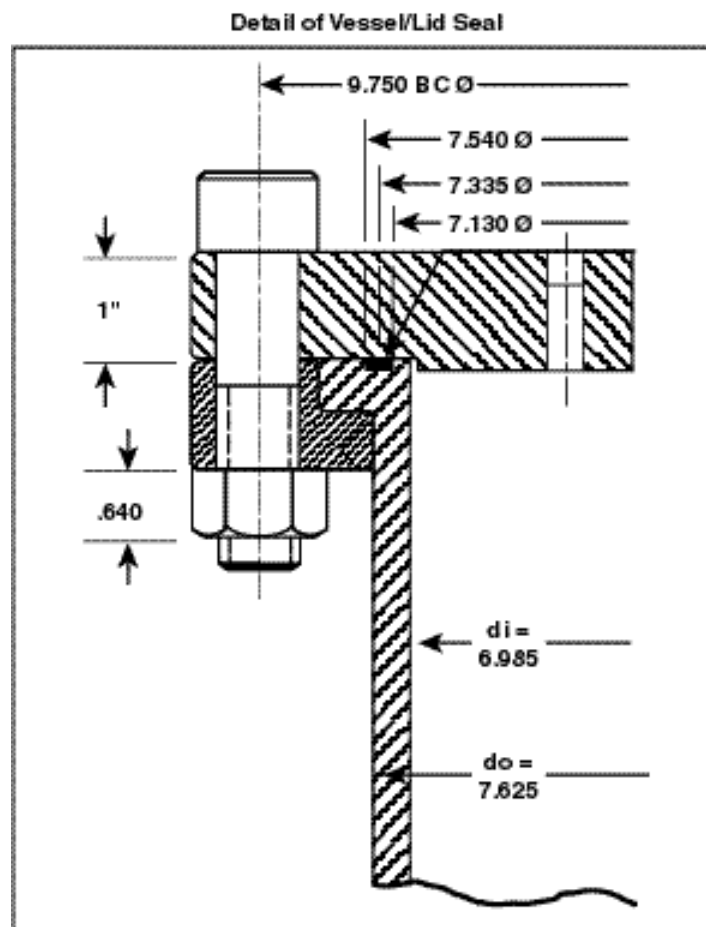
8 each – 3/4-10UNC Soc. HD

LLNL S/N 5305-20496

$S(\text{ultimate} = 160,000(\text{psig}) = S_{u-b}$

(Ref. [11])

$$S(\text{allowable}) = \frac{S_{u-b}}{4} = 40,000(\text{psi}) = S_{a-b}$$



- Nuts

LLNL S/N 5310-21810

$$S(\text{ultimate} = 90,000(\text{psig}) = S_{u-n} \quad (\text{Ref. [10]})$$

$$S(\text{allowable}) = \frac{S_{u-n}}{4} = 22,500(\text{psi}) = S_{a-n}$$

$$\text{Thickness of nut} = T_n = .640$$

C.1 Cylindrical Hoop Stress

$$r_o = 7.625/2 = 3.8125$$

$$r_i = 6.925/2 = 3.4925$$

$$R = r_o/r_i = 3.8125/3.4925 = 1.092 \dots (\text{use thin-wall equation})$$

$$P = \frac{S_{a-n} E t}{r_i} \quad (\text{pg. E-8, Eq.[1]. Ref. [1]})$$

Where $t = .320 \text{ in.}$

$$E = \text{joint efficiency} = 1^*$$

*This vessel contains no structural welds. In this design no strength credit is taken for the bottom seal weld. Rather, its only purpose is to provide a gas seal. The pressure load is fully taken by the 7-12 thread support.

Substituting values gives

$$P = \frac{18,800 \times .320}{3.4925} = 1,723(\text{psi})$$

Vessel (based on hoop stress) is good to 1,723(psig)

$$\text{Vessel MAWP} = 500 \text{ psig} \quad \text{OK}$$

C.2 Bottom Thickness

$$T = 1.0$$

$$T = d_i \sqrt{\frac{C P}{S_{a-n} E}} \quad (\text{pg. E-10, Eq. [9], Ref. [1]})$$

Where $C = \text{Attachment coefficient}$

$$= .75 \quad (\text{Case Q, pg. E-11, Ref. [1]})$$

Solving for P gives

$$P = \frac{S_a}{C} \frac{T}{d_i}^2$$

Substituting values gives

$$P = \frac{18,000}{.75} \frac{1}{6.985}^2 = 516(\text{psi})$$

Vessel (based on hoop stress) is good to 516 (psig)

Vessel MAWP = 500 psig **OK**

C.3 Bottom Thread Shear

Bottom thread is 7-12-2A × 1" long.

Thread form is

has = .02706 (pg. 62, Ref. [4])

Dm = Major diameter (external thread)
= 7.000

Dp = Pitch diameter
= 7.000 – 2 (.02706)
6.94558

Shear stress in the threads is given by

$$s = \frac{F}{A_s} \quad [1]$$

Where F = Force tending to shear the threads

= Design pressure × Area of bottom

$$= P \times \frac{\pi}{4} D_m^2 \quad [2]$$

A = Shear area of thread (pg 103, Ref. [5])

$$= \frac{EL_e}{2} \quad [3]$$

Where E = Minimum thread pitch diameter

= D_p (from page 6)

= 6.94558

L_e = Length of engagement

= Bottom thickness

= 1.0

Limiting this shear stress to one-half the design stress, as

$$s = \frac{\text{design stress}}{2} \quad (\text{Part 1, pg. 5, Ref. [6]})$$

$$s = \frac{S_{a-v}}{2} \quad [4]$$

Combining equations 1, 2, 3, and 4, and solving for P gives

$$P = \frac{S_a - EL_e}{D_m^2} \quad [5]$$

Substituting values into equation 5 gives

$$P = \frac{18,800 \times 6.94558 \times 1}{7^2} = 2,665(\text{psi})$$

Threads in vessel bottom good to 2,665 (psig)
Vessel MAWP = 500 psig **OK**

C.4 Lid Thickness

Cited references are from ASME Boiler and pressure Vessel Code, Section VIII, Division 1, 1992, (Ref. 7) unless otherwise stated.

The vessel lid thickness is

$$T = d \sqrt{\frac{CP}{S_a - E} + 1.9 \frac{Wh_g}{S_a - E d^3}} \quad (\text{Eq. [10], pg. E-10, Ref. [1]})$$

Where

C = attachment coefficient (Case K, pg. E-11, Ref. [1])

E = .3

E = 1 (pg E-13, Ref. [1])

h_g = Radial difference between bolt circle and pressure seal circle (1

= (9.75-7.335)/2 = 1.2075

d = pressure seal diameter = 7.335

W = flange design bolt load

Solving for P gives

$$P = \frac{T^2}{d^2} - \frac{1.9Wh_g}{S_{a-v}d^3} \frac{S_{a-v}}{C} \quad [6]$$

C.4.1 Determination of W

(Appendix 2, para. 2.5, pg. 312)

$$W = \text{largest of } \begin{matrix} W_{m1} \text{ (operating conditions)} \\ W_{m2} \text{ (gasket sealing)} \end{matrix}$$

$$W_{m1} = H + H_p \quad (\text{Eq. [1], pg. 313})$$

Where H_p = for self-energizing seals (o-ring) (Para C3a, pg. 313)

H = hydrostatic end force

$$= \frac{1}{4} G^2 P \quad (\text{Eq. [1], pg. 313})$$

$$G = d = 7.335$$

Substituting values gives

$$W_{m1} = \frac{1}{4} 7.335^2 \times 500 = 21,128(\text{lbs})$$

$$W_{m2} = 0 \text{ for self-energizing seals (o-rings)} \quad (\text{Para. C3b, pg. 313})$$

$$W = W_{m1} = 21,128(\text{lbs}) \text{ (operating conditions)}$$

C.4.2 Bolt

XS areas are determined as (pg. 310 and Para. C3d, pg. 313)

A_m = total required XS area of bolting

$$= \text{large of } \begin{matrix} A_{m1} \text{ (operating conditions)} \\ A_{m2} \text{ (gasket sealing)} \end{matrix}$$

$$A_{m1} = \frac{W_{m1}}{S_b}$$

$$S_a = \text{Allowable bolt stress at atmospheric temperature}$$

$$S_b = \text{Allowable bolt stress at operating temperature}$$

$$S_a = S_b = S_{a-b}$$

Substituting values gives

$$A_{m1} = \frac{21,128}{40,000} = 0.5282(\text{in}^2)$$

$$A_{m2} = \frac{W_{m2}}{S_a} = 0 \quad (\text{from above})$$

$$A_m = A_{m1} = 0.5282(\text{in}^2)$$

$$A_b = \text{actual total XS area of bolting}$$

$$= 8 \times \text{XS area of } 3/4\text{-}10 \text{ bolt}$$

$$= 8 \times .334 \text{ (pg. 8-12. Ref. [8])}$$

$$= 2.672(\text{in}^2)$$

$$A_b \quad A_m \quad \text{OK} \quad (\text{Para. C3d, pg. 313})$$

C.4.3 W for Gasket Seating

$$W = \frac{(A_m + A_b)S_{a-b}}{2} \quad (\text{Eq. [4], pg. 319})$$

The above equation applies to hard gaskets to protect them from over tightening and flange overloading. This equation does not apply to self-energizing seals (o-rings), as gasket seating loads are considered zero.

Thus,

$$W = W_{m1} = 21,128 \text{ (lbs).}$$

Finally, values are substituted into Eq. 6, page 8, to determine lid thickness, as:

$$P = \frac{1}{7.335}^2 - \frac{1.9 \times 21,128 \times 1.2075}{18,800 \times 7.335^3} \frac{18,800}{.3} = 755(\text{psi})$$

Vessel lid is good to 755 (psig)

Vessel MAWP = 500 psig **OK**

C.5 Lid Feed-Throughs

Three male threaded pipe feed-throughs are installed in the vessel lid. These stainless steel fittings have pressure ratings in excess of 3,000 (psig). The corresponding internally threaded holes in the vessel lid will be evaluated for their pressure rating based on thread shear stress. A conservative, approximate analysis for a tapered pipe thread can be made by using the minimum pitch diameter, E_o , outside pipe diameter, D , hand tight engagement length, L , and the equations of paragraph C.3, on page 6.

Pipe Size	$E_o = E$	D	$L_1 = L_e$	
1/8	.36351	.405	.1615	(pg. 1363, Ref. [9])
1/2	.75843	.840	.320	

As in paragraph C.3, Eq. 5, page 7,

$$P = \frac{S_{a-v} E L_e}{D^2}$$

Substituting values gives

$$P(1/8\text{thd}) = \frac{18,800 \times .3635 \times .1615}{.405^2} = 6,729(\text{psi})$$

$$P(1/2\text{thd}) = \frac{18,800 \times .75843 \times .320}{.840^2} = 6,466(\text{psi})$$

Vessel feed-through connections are good to 6,466(psig)+

Vessel MAWP = 500 psig **OK**

C.6 Bolt/Nut Thread Stress

Eight each 3/4-10 UNC nuts and bolts fasten the vessel lid to the vessel. As in equation [5], page 7, the pressure-stress relationship for this thread system can be shown to be:

- Bolts

$$P = 8 \frac{S_{a-b} E L_e}{D^2}$$

Where E = pitch diameter of the external thread (bolt)

$$= .6773 \quad (\text{Ref. [4]})$$

L_e = thickness of the nut

$$= .640 \quad (\text{Ref. [10]})$$

D = o-ring seal diameter

$$= 7.335 \quad (\text{Ref. pg. 4})$$

Substituting values gives

$$P = 8 \frac{40,000 \times .6773 \times .640}{7.335^2} = 2,578(\text{psi})$$

Bolts are good to 2,578(psig).

Vessel MAWP = 500 psig **OK**

- Nuts

$$P = 8 \frac{S_{a-n} E L_e}{D^2}$$

Where E = pitch diameter of the external thread (nut)

$$= .6850 \quad (\text{Ref. [4]})$$

Substituting values gives:

$$P = 8 \frac{22,500 \times .6850 \times .640}{7.335^2} = 1,467(\text{psi})$$

Bolts are good to 1,467(psig).

Vessel MAWP = 500 psig **OK**

D. Pressure Testing

The assembled vessel shall be pressure tested as follows:

1. Pressure test with helium to 1.5 times MAWP; i.e., $1.5 \times 500 = 750$ (psig). Hold pressure a minimum of 30 minutes.
2. Leak check with helium to 1 times MAWP; i.e, 500(psig). Any leakage detectable with a mass spectrometer leak detector hand probe is unacceptable.

All tests shall be performed by a high-pressure technician and witnessed by an LLNL pressure inspector.

D.1 Maximum Energy of Distortion Analysis

To ensure that this vessel does not yield during this 1.5 times MAWP pressure test, the following "Maximum Energy of Distortion Analysis" calculation is performed.

(Reference pg. E-25, Ref [1])

Stress at test pressure = S_{vm} (combined Von Mises stress)

$$S_{vm} = \sqrt{\frac{1}{2}[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2]} \quad [7]$$

$$\text{Define } Z = \frac{r_o}{r_i} = \frac{3.8125}{3.4925} = 1.192$$

$$\begin{aligned} S_1 &= \frac{P}{Z - 1} \\ &= \frac{750}{1.192 - 1} \\ &= 3,906(\text{psig}) \end{aligned}$$

$$\begin{aligned} S_2 &= P \times \frac{Z + 1}{Z - 1} \\ &= 750 \frac{1.192 + 1}{1.192 - 1} \\ &= 8,562(\text{psig}) \end{aligned}$$

$$\begin{aligned} S_3 &= -P \\ &= -750(\text{psig}) \end{aligned}$$

Substituting into equation [7] gives the following

$$S_{vm} = 8,064(\text{psig})$$

N = Ratio of yield strength to combined stress

N 1 to ensure no yielding

$$S_y = 30,000(\text{psig}) \quad (\text{from pg. 3})$$

$$N = \frac{30,000}{8,064} = 3.72$$

Cylindrical vessel section will not yield during 1.5 times MAWP pressure test.

E. Re-test/Re-inspection

This system requires a re-inspection every three years and a re-test every six years. These shall be performed by an LLNL high-pressure technician and witnessed by an LLNL pressure inspector. Re-testing shall be done at 1 times the manned area MAWP previously defined in paragraph D.

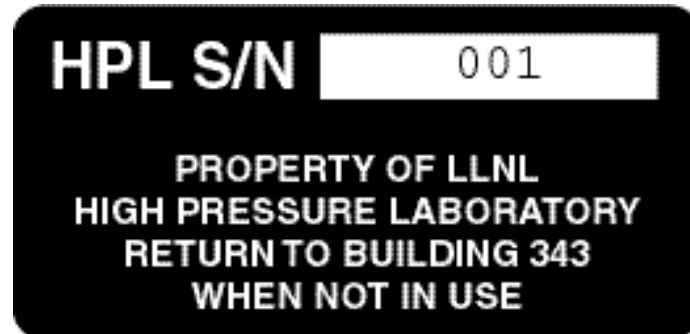
F. Labeling

The pressure inspector will certify the inspection of this system by completion of an LLNL Pressure Test/Inspection Record, Form LL3586, and by attaching an LLNL Pressure Tested Label, filled out as follows:

LLNL PRESSURE TESTED			
FOR MANNED AREA			
ASSY.	AAA 88-111930		
SAFETY NOTE	MESN 99-001-0A		
M.A.W.P.	500	PSIG.	
FLUID	INERT LIQUID / GAS		
TEMP.	32	TO	130 °F
REMARKS			
TEST NO.	ME 1343	T.R.	
EXPIRATION DATE			
BY		DATE	

G. Special Use Label

This item may be part of the High Pressure Testing Facility equipment inventory. In this category, it is maintained, utilized, and controlled by that facility. Such equipment may be made available, on a loan basis, to other LLNL projects. If in this category, the following label will be affixed:



H. Associated Documentation

1. AAA 88-111390 500(psig) test vessel
2. M.E. 1343 M.E. Test/Inspection Record for 500(psig) test vessel.

I. References

1. DOE Pressure Safety Manual, December 1993.
2. ASME Boiler and Pressure Vessel Code, Section 2, part D, subpart 1, table 1A, page 98.
3. ASME Boiler and Pressure Vessel Code, Section 2, part D, subpart 1, table 1A, page 98.
4. ASA B1.1 – 1960, Unified Screw Threads, ASME.
5. NBS 1963 Supplement to Screw-thread Standards for Federal Service, 1963 Supplement to H-28.
6. NBS Screw Thread Standards for Federal Service, Handbook H-28 (1957), part 1.
7. ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, 1992.
8. Marks Standard Handbook for Mechanical Engineers, 9th edition.
9. Machinery Handbook, 22nd edition.
10. LLNL ESR #354-5A.
11. LLNL ESR #283-1C.

23160 BY

LAWRENCE BATHURST LABORATORY

STANLEY A. LEE, JR., 10000 15TH AVE. S.W., SEASIDE, CALIF. 94065

SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301-1500
404-700-4344

UNCL Source: FBI, New York, Bureau, 107 pages, dated 1968. State U Number
 Case no. 100-86840, New York file.

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NOTES: 1. $\alpha = 0.05$ for all tests.
2. $\alpha = 0.05$ for all tests.

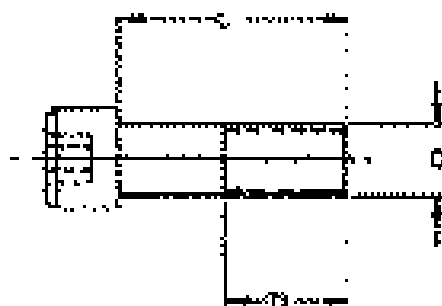
TO: SAC, NEW YORK (100-388610) FROM: SAC, NEW YORK (100-388610) (P)
SUBJECT: [REDACTED] (P)
RE: [REDACTED] (P)

1999:28

100% CUP, 40% LIGN, 20% PAPER, 10% GLASS, 10% METAL, 10% PLASTIC, 10% RUBBER, 10% LEATHER, 10% WOOD, 10% STONE, 10% BRICK, 10% CEMENT, 10% CONCRETE, 10% ASPHALT, 10% PAINT, 10% GLUE, 10% NAIL, 10% SCREW, 10% BOLT, 10% WIRE, 10% CABLE, 10% PIPE, 10% TUBE, 10% SHEET, 10% BOARD, 10% PANEL, 10% DOOR, 10% WINDOW, 10% FLOOR, 10% CEILING, 10% WALL, 10% ROOF, 10% GROUND, 10% AIR, 10% WATER, 10% FIRE, 10% EARTH, 10% SUN, 10% MOON, 10% STAR, 10% PLANET, 10% GALAXY, 10% UNIVERSE, 10% TIME, 10% SPACE, 10% MATTER, 10% ENERGY, 10% FORCE, 10% MOTION, 10% SOUND, 10% LIGHT, 10% HEAT, 10% COLD, 10% WIND, 10% RAIN, 10% SNOW, 10% HAIL, 10% FOG, 10% CLOUD, 10% RAINBOW, 10% SUNSHINE, 10% SHADOW, 10% REFLECTION, 10% REFRACTION, 10% DIFFRACTION, 10% INTERFERENCE, 10% POLARIZATION, 10% COHERENCE, 10% MONITOR, 10% SPEAKER, 10% MICROPHONE, 10% CAMERA, 10% TELEVISION, 10% RADIO, 10% TELEPHONE, 10% COMPUTER, 10% INTERNET, 10% MOBILE PHONE, 10% VIDEO, 10% MUSIC, 10% BOOK, 10% MAGAZINE, 10% NEWSPAPER, 10% JOURNAL, 10% PAPER, 10% CAR, 10% TRUCK, 10% BUS, 10% TRAIN, 10% AIRPLANE, 10% SHIP, 10% BOAT, 10% YACHT, 10% MOTORCYCLE, 10% BICYCLE, 10% SKATEBOARD, 10% SKI, 10% SNOWBOARD, 10% HOCKEY, 10% BASKETBALL, 10% SOCCER, 10% TENNIS, 10% GOLF, 10% BASEBALL, 10% FOOTBALL, 10% HANDBALL, 10% VOLLEYBALL, 10% BADMINTON, 10% TABLE TENNIS, 10% JUDO, 10% KARATE, 10% JIU JITSU, 10% MMA, 10% BOXING, 10% WRESTLING, 10% GYM, 10% YOGA, 10% PILATES, 10% DANCE, 10% MUSIC, 10% ART, 10% CRAFT, 10% COOKING, 10% BAKING, 10% GARDENING, 10% FISHING, 10% HUNTING, 10% TRAVEL, 10% TOURISM, 10% HOTELS, 10% RESTAURANTS, 10% CLOTHING, 10% SHOES, 10% ACCESSORIES, 10% JEWELRY, 10% WATCHES, 10% CLOCKS, 10% CALCULATORS, 10% RULERS, 10% COMPASSES, 10% PROTRACTORS, 10% SET SQUARES, 10% SCISSORS, 10% KNIVES, 10% HAMMERS, 10% DRILLS, 10% SAWS, 10% SANDPAPERS, 10% GLASS, 10% METAL, 10% PLASTIC, 10% RUBBER, 10% LEATHER, 10% WOOD, 10% STONE, 10% BRICK, 10% CEMENT, 10% CONCRETE, 10% ASPHALT, 10% PAINT, 10% GLUE, 10% NAIL, 10% SCREW, 10% 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ACCESSORIES,

Shaw, R. 1997. *Journal of the American Statistical Association* 92: 1001-1010.

Innovation	Firm size	
	Small	Large
new product	0.28	0.25
new process	0.19	0.19
new market	0.24	0.18
new combination	..	0.26
new plant	..	0.26
new management	..	0.25
new technology	..	0.27
new product/management	0.26	0.19



11 May 2007 14:16:45 AM (GMT) 200705110303

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- 1007-1008-1009-1010

22 JUL 1976

[illegible]

1. Yes, I would like to be a member.

FOR LL USE ONLY

Prepared by: Katherine Wadkins
 Date: January 16, 1973

ENGINEERING STANDARD REFERENCE

LRL Stock Class 1112
 MESN No. 850-54
 Page 2 of 2

ISSUED BY

LAWRENCE RADIATION LABORATORY STANDARD & SPECIALTY DIVISION MECHANICAL ENGINEERING DIVISION

SPECIFICATION FF-N-0163
 SPECIFICATION 143-0015-0

IRL STOCK

ILL Stock No.	IRL Thread	IRL Threads	IRL Threads Across Flat Top	IRL Threads Across Bottom	IRL Threads Across Top	Price	Vendor No.	Qty	Notes
11.0-011819		0-50	1-12	1-12	1-12				
11.0-011820		1-72	1-12	1-12	1-12				
11.0-011821	2-54		1-12	1-12	1-12				
11.0-011822	1-48		1-12	1-12	1-12				
11.0-011823		1-56	1-12	1-12	1-12				
11.0-011824	4-48		1-12	1-12	1-12				
11.0-011825	1-48		1-12	1-12	1-12				
11.0-011826	1-48		1-12	1-12	1-12				
11.0-011827		1-56	1-12	1-12	1-12				
11.0-011828	1-48		1-12	1-12	1-12				
11.0-011829	1-48		1-12	1-12	1-12				
11.0-011830	1-48		1-12	1-12	1-12				
11.0-011831	1-48		1-12	1-12	1-12				
11.0-011832	1-48		1-12	1-12	1-12				
11.0-011833	1-48		1-12	1-12	1-12				
11.0-011834	1-48		1-12	1-12	1-12				
11.0-011835	1-48		1-12	1-12	1-12				
11.0-011836	1-48		1-12	1-12	1-12				
11.0-011837	1-48		1-12	1-12	1-12				
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